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POWER TRANSMISSION CHAIN AND POWER TRANSMISSION DEVICE

TECHNICAL FIELD

The present invention relates to a power transmission chain, and in more detail, to a power transmission chain preferable for a continuously variable transmission (CVT) of an automobile.

BACKGROUND ART

As a continuously variable transmission for an automobile, there has been known one which includes: a drive pulley (2), having a fixed sheave (2a) and a movable sheave (2b), provided on the engine side; a driven pulley (3), having a fixed sheave (3b) and a movable sheave (3a), provided on the drive wheel side; and an endless power transmission chain (1) provided over the both, and in which the movable sheaves (2b) (3a) are caused to come close to or leave away from the fixed sheaves (2a) (3b) by a hydraulic actuator, whereby a chain (1) is cramped by a hydraulic pressure so as to cause a contact load between the pulleys (2) (3) and the chain (1), and torque is transmitted by a frictional force of the contact part, as shown in Fig. 18.

As the power transmission chain, Patent Document 1 (Publication of Japanese Patent Application Laid-open No.

H08-312725) proposes one which includes: a plurality of links having front and back insertion parts through which pins are inserted; and a plurality of first pins and a plurality of second pins for connecting the links aligned in a chain width direction so as to be bendable in a longitudinal direction such that a front insertion part of one link and a back insertion part of another link correspond to each other, in which a first pin fixed to a front insertion part of one link and movably fitted in a back insertion part of another link and a second pin movably fitted in the front insertion part of the one link and fixed to the back insertion part of the other link move relatively in a rolling and contacting manner so as to enable bending in a longitudinal direction between the links.

The power transmission chain of Patent Document 1 suppresses polygonal vibration caused due to the fact that the chain is not a continuum and reduces noises of a continuously variable transmission using it. However, in order to enhance quietness and to improve comfort of an automobile in which the chain is mounted, for example, it is preferable to further reduce noises.

An object of the present invention is to provide a power transmission chain and a power transmission device capable of suppressing polygonal vibration to thereby

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remove causes of noises.

DISCLOSURE OF THE INVENTION

A power transmission chain according to the present invention includes: a plurality of links having front and back insertion parts through which pins are inserted; and a plurality of first pins and a plurality of second pins for connecting the links aligned in a chain width direction so as to be bendable in a longitudinal direction such that a front insertion part of one link and a back insertion part of another link correspond to each other, in which a first pin fixed to a front insertion part of one link and movably fitted in a back insertion part of another link and a second pin movably fitted in the front insertion part of the one link and fixed to the back insertion part of the other link move relatively in a rolling and contacting manner so as to enable bending in a longitudinal direction between the links, wherein at least two kinds of sets of pins are provided in which loci of rolling contact movement of the first pin and the second pin are different, and the sets of pins are aligned randomly.

The first pin and the second pin are so formed that a contact surface of one pin is flat, and a contact surface of the other pin is a curved surface required for enabling rolling contact movement relatively, for example. In this

case, since at least two kinds of required curved surfaces (e.g., one having large curvature relatively and one having small curvature relatively) are formed, sets of pins are obtained in which loci of rolling contact movements are different. The first pin and the second pin may be formed such that the respective contact surfaces are required curved surfaces. In such a case, since the contact surface shapes of the respective pins are formed in at least two kinds respectively (e.g., one having large curvature relatively and one having small curvature relatively), sets of pins are obtained in which loci of rolling contact movements are different.

The two kinds of sets of pins may be the same number or almost the same number, but a case where one is about twice or about five times as large as the other is also acceptable.

In order to obtain at least two kinds of sets in which loci of rolling contact movements of the first pins and the second pins are different, it is only necessary to form two or more kinds of sets of the first pins and the second pins in which the locus of a contact position of a first pin and a second pin is an involute of a circle and basic circle radii of the involutes are different.

In the power transmission chain, it is preferable that two or more kinds of links having different pitches be

formed, and the links be aligned randomly.

A pitch means an interval between the front and back insertion parts. By changing the interval between the front and back insertion parts while keeping the shapes of the insertion parts to be same, links of different pitches are obtained. The size of a link itself may be changed corresponding to a pitch, or not to be changed. The two kinds of pitches (links) may be in the same number or almost the same number, but a case where one is about twice or about five times as large as the other is also acceptable. Further, the number may be determined so as to correspond to the number of sets of pins, or the number may be determined irrespective of the number of sets of pins.

Assuming that a contact position of the first pin and the second pin in a chain linear part is an origin, a chain linear direction is an x axis, a direction orthogonal thereto is a y axis, and an angle defined by a pin tangential direction with respect to the y axis at a contact position of the first pin and the second pin in a chain curved part is γ, an involute curve of a circle whose basic circle radius is Rb is obtained by the following equations.

$$x = Rb \cdot (\sin\gamma - \gamma \cdot \cos\gamma)$$

$$y = Rb \cdot (\cos\gamma + \gamma \cdot \sin\gamma) - Rb$$

When it is used as a chain for a CVT, assuming a

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minimum radius of the chain curved part when used as a
chain for the CVT is R, and transmission ratio of the CVT
is r, it is preferable that the following relationships be
established:

Rb=k·R

0.25<k<2r

That is, it is preferable that two kinds (three kinds
or more if required) of involute curves be selected from
arbitrary involute curves between an involute curve where
k=0.25 (allowable lower limit curve) and an involute curve
where k=2r (allowable upper limit curve) in the following
equations.

x=k·R·(sinγ−γ·cosγ)

y=k·R·(cosγ+γ·sinγ)−k·R

As for a locus of the rolling contact movement, the
locus of a contact position of the first pin and the second
pin is not limited to an involute of a circle, and may be a
non-involute curve (involute similar curve) between an
involute curve where k=0.25 (allowable lower limit curve)
and an involute curve where k=2r (allowable upper limit
curve).

One of the first pin and the second pin is a pin
which contacts a pulley when the chain is used in a
continuously variable transmission (hereinafter referred to
as "pin"), and the other one is a pin not contacting the

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pulley (called interpiece or strip, hereinafter referred to as "interpiece").

A front insertion part of a link consists of a pin fixing part to which a pin is fixed and an interpiece movable part in which an interpiece is movably fitted, and a back insertion part of a link consists of a pin movable part in which a pin is movably fitted and an interpiece fixed part to which an interpiece is fixed. Front and back insertion parts may be formed such that front and back through holes separated each other are formed in a link, in which the front through hole is the front insertion part and the back through hole is the back insertion part. Alternatively, a through hole elongated in front and back may be formed in a link, in which the front part of the through hole is the front insertion part and the back part of the through hole is the back insertion part.

Although, in the present specification, one end side in a longitudinal direction of a link is front and the other end side is back, these front and back are for convenience, and it does not mean the longitudinal direction of a link always coincides with a front and back direction.

In the power transmission chain of the present invention, the number of sets of pins in which loci of rolling contact movements are different may be any number,

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provided it is two or more. When the number of sets of
pins having different loci increases, the manufacturing
cost increases, and the effect is not proportional to the
number, so it is sufficient that the number of sets of pins
having different loci is five or less. Even though the
sets of pins having different loci are two kinds, it is
possible to prevent resonance due to polygonal vibration by
aligning them randomly, whereby it is possible to
significantly reduce noises caused by the chain.

Further, the number of links having different pitches
may be any number, provided it is two or more. By making
pitches in random order, it is possible to prevent energy
concentration of impact force between a pin and a pulley.

When the pitch becomes larger, amplitude and an angle
of approach become larger, so vibration is tend to be
larger. Therefore, as for those having large pitch, it is
preferable to enlarge the basic circle radius so as to
reduce the angle of approach. When the number of pitches
increases, the manufacturing cost increases, so it is
sufficient that the number of pitches is five or less.
Even if the pitches are of two kinds, by aligning sets of
pins having different loci and aligning the pitches
randomly, it is possible to significantly prevent resonance
of polygonal vibration.

In the above description, when aligning sets of pins

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of different shapes and links of different pitches randomly, it is more preferable that at least one (preferably 2 or more) of the following four conditions be satisfied.

A) No alignment number of the same kind of elements appears within a range of ±5% on the basis of any point.

B) The alignment number of the largest frequency does not exceed three times as large as the alignment number of the smallest frequency existing.

C) Kinds of continuous alignment number of the same kind of elements including different types of elements exceeds three kinds.

D) A part having rotational symmetry of alignment patterns of 60 degrees or less does not exceed 50% of the whole.

In this specification, a "random alignment" means at least one of the above-described four conditions is satisfied in a narrow sense. However, a case in which an alignment of "abbabb" is provided for only one part for example, and parts other than this satisfy A) should be considered as a random alignment. A "random alignment" is considered as to include those in which respective elements are aligned without periodicity and regularity in only one part of the whole as well as those in which respective elements are aligned without periodicity and regularity throughout.

The power transmission chain is, for example, one in

which the locus of a contact position of a first pin and a second pin is an involute of a circle and two kinds or more links having different pitches are formed, and a basic circle radius of an involute in a link having a large pitch is larger than a basic circle radius of an involute in a link having a small pitch.

In a power transmission chain including: a plurality of links having front and back insertion parts through which pins are inserted; and a plurality of first pins and a plurality of second pins for connecting the links aligned in a chain width direction so as to be bendable in a longitudinal direction such that a front insertion part of one link and a back insertion part of another link correspond to each other, in which a first pin fixed to the front insertion part of one link and movably fitted in the back insertion part of another link and a second pin movably fitted in the front insertion part of the one link and fixed to the back insertion part of the other link move in a rolling and contacting manner relatively so as to enable bending in a longitudinal direction between the links, there is a case where the locus of a contact position of the first pin and the second pin is an involute of a circle, and [radius of basic circle of involute]/[height of pin]=5 to 20.

By increasing the basic circle radius of the involute,

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the angle of approach can be smaller, so due to an effect
of the angle of approach being decreased, it is possible to
reduce noises and vibration of the chain. In a
continuously variable transmission for an automobile, the
height of a pin is about 4 to 20mm, and a basic circle
diameter is preferably about 5 to 20 times as large as it,
and more preferably 9 to 17 times, and yet more preferably,
11 to 15 times. A first pin and a second pin have the
almost same height, and either pin may be a base pin, but
more strictly, a longer pin, that is, a pin in which end
faces thereof contact conical sheave faces of a pulley of
the continuously variable transmission is the base. For
one in which the locus of a contact position of a first pin
and a second pin is an involute of a circle, and [radius of
basic circle of involute]/[height of pin]=5 to 20, it is
possible to suppress polygonal vibration effectively even
in a case of one set of pins, whereby causes of noises can
be removed.

A configuration in which [radius of basic circle of
involute]/[height of pin]=5 to 20 is capable of suppressing
polygonal vibration and further removing causes of noises,
by being combined with a power transmission chain having
two kinds of sets of pins.

In order to have the locus of a contact position of
pins moving in a rolling and contacting manner relatively

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to be an involute curve, it is only necessary that a contact surface of one pin is in the involute shape having the basic circle of the radius Rb in a section, and a contact surface of the other pin is flat (sectional shape is a line), for example.

The locus of a contact position of pins may be an involute curve of a circle although both contact surfaces of the pins are curved surfaces. For example, sectional shapes of a first pin and a second pin may be same, and the locus of a contact position of the first pin and the second pin may be an involute curve of a circle. In this case, assuming that an x directional relative distance between a sectional curve g1(y) of a contact surface on the pin side and a sectional curve g2(y) of a contact surface on the interpiece side is Lx=f(y) (x: chain travel direction coordinate, y: radial direction coordinate), g1=-g2, and Lx is an involute curve of a circle.

It is preferable that the power transmission chain described above be one in which one pin (interpiece) is shorter than the other pin (pin), and end faces of the longer pin contact conical sheave faces of a pulley of the continuously variable transmission, and power is transmitted by a frictional force caused by this contact. Each pulley consists of a fixing sheave having a conical sheave face and a movable sheave having a conical sheave

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face facing the sheave face of the fixing sheave, and a chain is interposed between the sheave faces of the both sheaves, and the movable sheave is moved by a hydraulic actuator whereby a winding radius of the chain changes depending on the distance between the sheave faces of the continuously variable transmission, which enables variable transmission continuously with smooth movement.

A power transmission device according to the present invention includes a first pulley having a sheave face in a conical surface shape, a second pulley having a sheave face in a conical surface shape, and a power transmission chain is provided over the first and second pulleys, and the power transmission chain is one of those described above.

The power transmission device becomes one preferable to be used as a continuously variable transmission of an automobile.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a plan view showing a part of a power transmission chain according to the present invention.

Fig. 2 is an enlarged perspective view of the same.

Fig. 3 is an enlarged side view of the same.

Fig. 4 is a diagram for explaining a basic circle radius of a contact surface.

Fig. 5 is a diagram showing a moving locus of a pin.

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Fig. 6 is a graph showing a sound pressure level when equal pitch alignment is adopted.

Fig. 7 is a diagram showing an example where pins of different shapes are aligned randomly.

Fig. 8 is a diagram showing an example where links of different shapes are aligned randomly.

Fig. 9 shows tables of examples of basic circle radii of a power transmission chain and random alignments according to the present invention.

Fig. 10 shows tables shows tables examples of pitches and basic circle radii of a power transmission chain and random alignments according to the present invention.

Fig. 11 shows charts of relationships between pitch and amplitude and between pitch and angle of approach.

Fig. 12 shows charts of relationships between a basic circle radius and an amplitude and between a basic circle radius and an angle of approach.

Fig. 13 is a diagram showing states of a pin before and after biting of a power transmission chain according to the present invention.

Fig. 14 is a chart showing a range of preferable contact surface shape of a pin of the power transmission chain according to the present invention.

Fig. 15 is a diagram, corresponding to Fig. 3, showing another embodiment of power transmission chain

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according to the present invention.

Fig. 16 shows diagrams illustrating another embodiment in a ring shape of a power transmission chain according to the present invention.

Fig. 17 is a front view showing a state where a power transmission chain is mounted on a pulley.

Fig. 18 is a perspective view showing an example of a continuously variable transmission in which a power transmission chain according to the present invention is used.

BEST MODE FOR CARRYING OUT THE INVENTION

Hereinafter, an embodiment of the present invention will be explained with reference to the drawings. In the explanation below, the left in Fig. 3 is called front and the right thereof is called back.

Figs. 1 and 2 show a part of a power transmission chain according to the present invention. A power transmission chain (1) includes: a plurality of links (11) having front and back insertion parts (12) (13) provided at predetermined intervals in a chain length direction; and a plurality of pins (first pins) (14) and interpieces (second pins) (15) for connecting links (11) aligned in a chain width direction so as to be bendable in a longitudinal direction (chain length direction).

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As shown in Fig. 3, the front insertion part (12)
consists of a pin fixing part (12a) to which a pin (14)
(shown by a continuous line) is fixed and an interpiece
movable part (12b) in which an interpiece (15) (shown by an
alternate long and two short dashes line) is movably fitted,
and the back insertion part (13) consists of a pin movable
part (13a) in which a pin (14) (shown by an alternate long
and two short dashes line) is movably fitted and an
interpiece fixing part (13b) to which an interpiece (15)
(shown by a continuous line) is fixed. In connecting the
links (11) aligned in a chain width direction, links (11)
are overlapped with each other such that the front
insertion part (12) of one link (11) and the back insertion
part (13) of another link (11) correspond to each other,
and the pin (14) is fixed to the front insertion part (12)
of one link (11) and is movably fitted in the back
insertion part (13) of another link (11), and the
interpiece (15) is movably fitted in the front insertion
part (12) of one link (11) and is fixed to the back
insertion part (13) of another link (11). Then, the pin
(14) and the interpiece (15) move in a rolling and
contacting manner relatively so as to enable bending in a
longitudinal direction (front and back direction) of the
links (11).

The locus of a contact position of the pin (14) and

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the interpiece (15), based on the pin (14), is an involute
of a circle. In this embodiment, a contact surface (14a)
of the pin (14) is in an involute shape having a basic
circle of a radius Rb and the center M in a section as
shown in Fig. 4, and a contact surface (15a) of the
interpiece (15) is flat (sectional shape is a line).
Thereby, when each link (11) moves from the linear part to
the circular part or moves from the circular part to the
linear part of the chain (1), in the front insertion part
(12), the interpiece (15) moves such that the contact
surface (15a) thereof rolling-contacts the contact surface
(14a) of the pin (14) with respect to the fixed pin (14) in
the interpiece movable part (12b) (strictly, it is a
rolling contact including a slight sliding contact (rolling
sliding contact)), and in the back insertion part (13), the
pin (14) moves, in the pin movable part (13a), such that
the contact surface (14a) thereof rolling-contacts the
contact surface (15a) of the interpiece (15) with respect
to the fixed interpiece (15) (strictly, it is a rolling
contact including a slight sliding contact (rolling sliding
contact)). In Fig. 3, the parts shown by the reference
marks A and B are lines (points in the section) where the
pin (14) and the interpiece (15) contact each other in the
linear part of the chain (1), and the distance between A
and B is considered as a pitch in this specification.

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In such a power transmission chain (1), there is
caused polygonal vibration with the moving locus of the pin
shown in Fig. 5. In Fig. 5, in a biting position where the
pin (shown by a square mark) moves from the linear part to
the circular part contacting a pulley, a tangential
direction of the pulley and an approaching direction of the
pin are different (an angle defined by these directions is
an angle of approach), and the pin contacts the pulley
while moving downward. The fall amount of the pin, when
contacting the pulley, is shown as initial biting position
changing amount. The pin located at the linear part also
moves up and down affected by the fall of the pin located
at the biting position, and the movement amount in up and
down becomes amplitude. Through repetition of such up and
down movement of the pin, polygonal vibration is caused.

Since the pin (14) and the interpiece (15) move in a
rolling and contacting manner relatively and the locus of a
contact position of the pin (14) and the interpiece (15) is
an involute of a circle, the amplitude can be smaller
comparing with the case where both contact surfaces of the
pin and the interpiece are circular faces. However, even
with this configuration, if there is only one kind of link
(11) and the pin (14) and the interpiece (15) are used and
no action is taken for reducing vibration, a peak of large
sound pressure level is caused as shown in Fig.6, which is

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felt as a noise for a human. Therefore, even for one in
which the locus of a contact position is an involute of a
circle, it is desirable to further reduce polygonal
vibration.

In view of the above, in the power transmission chain
according to the present invention, not all of the links
(11), the pins (14) and the interpieces (15) are in the
same shapes. In order to prevent resonance caused by
polygonal vibration, plural kinds of sets of pins (14A)
(14B) and interpieces (15A) (15B) having different radii R1
and R2 of basic circles are used as shown in Fig. 7, and
preferably, links (11A) (11B) of different pitches P1 and
P2 are used as shown in Fog.8.

In contrast to the fact that all links, pins and
interpieces conventionally have the same pitch P1 and the
same radius R1 of a basic circle as shown in Fig. 9(c), in
a first embodiment of the power transmission chain (1)
according to this invention, as shown in Fig. 9(a), two
kinds of pins (14A) (14B) shown in Fig. 7 are used and the
pitch P1 is the same in all of them, and the sizes of the
basic circles are different such that if the basic circle
radius of the involute of the pin (14A) of a first set is
R1, the basic circle radius of the involute of the pin
(14B) of a second set is R2, the basic circle radius of the
involute of the pin (14B) of a third set is R2, and the

basic circle radius of the involute of the pin (14A) of a
fourth set is R1, and are aligned in irregular order
(random order).

Further, in a second embodiment of the power
transmission chain (1) according to this invention, as
shown in Fig. 9(b), three kinds of pins (not shown) are
used and the pitch P1 is the same in all of them, and the
sizes of the basic circles are different such that if the
basic circle radius of the involute of the pin of a first
set is R1, the basic circle radius of the involute of the
pin of a second set is R2, the basic circle radius of the
involute of the pin of a third set is R1, and the basic
circle radius of the involute of the pin of a fourth set is
R3, and are aligned in irregular order (randomly).

In order to manufacture two kinds of sets of pins
(14A) (14B) and interpieces (15A) (15B) in which the basic
circle radii are different, the shapes of the links (11)
are same including the insertion parts (12) (13), and the
contact surface (14a) of the pin (14A) is formed to be in
an involute shape having a basic circle of the radius R1,
and the contact surface (14a) of the pin (14B) is formed to
be in an involute shape having a basic circle of the radius
R2, and the interpieces (15A) (15B) are of one kind in
which the contact surface (15a) is flat. As for the pins
(14A) (14B) and the interpieces (15A) (15B), the sectional

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shapes may be reversed, or the locus of a contact position of the pin and the interpiece may be an involute of a circle and the pin and the interpiece may have the same sectional shape.

Although all links, pins and interpieces conventionally have the same pitch P1 and the same radius R1 of the basic circle as shown in Fig. 10(c), in another embodiment of the power transmission chain according to the invention, pitches are set randomly and the basic circle radius are changed corresponding thereto, as shown in Figs. 10(a) and 10(b).

In a third embodiment of the power transmission chain (1) according to the present invention, as shown in Fig. 10(a), two kinds of links (11A) (11B) shown in Fig. 8 and two kinds of pins (14A) (14B) and interpieces (15A) (15B) shown in Fig. 7 are used, and the sizes of pitches are different such that if the pitch of a first link (11A) is P1, the pitch of a second link (11B) is P2, the pitch of a third link (11B) is P2, and the pitch of a fourth link (11A) is P1, and they are aligned in irregular order (randomly). Then, if the pitch is P1, the basic circle radius of the involute of the pin (14A) is R1, and if the pitch is P2, the basic circle radius of the involute of the pin (14B) is R2 (where R1<R2 when P1<P2).

In a fourth embodiment of the power transmission

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chain (1) of the present invention, as shown in Fig. 10(b),

three kinds of links, pins and interpieces (not shown) are

used, and the sizes of pitches are different such that if

the pitch of a first link is P1, the pitch of a second link

is P2, the pitch of a third link is P1, and the pitch of a

fourth link is P3, and they are aligned in irregular order

(randomly). Then, if the pitch is P1, the basic circle

radius of the involute of the pin is R1, and if the pitch

is P2, the basic circle radius of the involute of the pin

is R2, and if the pitch is P3, the basic circle radius of

the involute of the pin is R3 (where R1<R2<R3 when

P1<P2<P3).

Note that the relationship between a pitch and a

basic circle is not required to satisfy a condition of

R1<R2 when P1<P2, and the same effect can be obtained from

R1>R2 when P1<P2. However, when a pitch is increased,

amplitude also becomes larger as shown in Fig. 11(a), and

angle of approach also becomes larger as shown in Fig.

11(b), which causes a demerit that vibration increases

since amplitude and angle of approach are large.

As for relationships between the basic circle radius

and the amplitude, and between the basic circle radius and

the angle of approach, the amplitude does not increase much

although the basic circle radius increases as shown in Fig.

12(a), and an angle of approach can be smaller when the

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basic circle radius is increased as shown in Fig. 12(b).
As a result, as the basic circle radius increases, a
vibration improving effect can be achieved associating with
a decrease in an angle of approach. Therefore, in the
power transmission chain (1) of the third and fourth
embodiments, R1<R2 when P1<P2 or R1<R2<R3 when P1<P2<P3,
and for those in which the pitch is large, the basic circle
radius is set to be large and an angle of approach is set
to be small, whereby a demerit associating with the pitch
being large is solved. Note that in Fig. 12, a large
rotational radius is R=73.859, and a small rotational
radius is set to R=31.65mm. Further, the Figure shows a
case where the height of a pin is 6mm, and in such a case,
it is found that Rb>51mm is preferable, and Rb≥70mm is more
preferable.

The shape of an involute is expressed by equations
$x=Rb \cdot (\sin\gamma - \gamma \cdot \cos\gamma)$ and $y=Rb \cdot (\cos\gamma + \gamma \cdot \sin\gamma) - Rb$, where Rb is
the radius of the basic circle and γ is the angle. The
length $Le(\gamma)$ of the involute shape is $Le(\gamma) = \int (x^2 + y^2)^{1/2} d\gamma$. By
integrating this from $\gamma=0$ to γ, $Le(\gamma) = Rb\gamma^2/2$ is obtained.
The height h of a pin is, assuming that it is proportional
to the length of Le, $h = a*Le = aRb\gamma^2/2$, where "a" is a
coefficient.

From this equation, it is found that h is also
proportional to Rb. The height of a pin used in a

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continuously variable transmission of an automobile is about h=4 to 20mm, and preferably, the range is Rb/h=5 to 20, and more preferably, Rb/h=9 to 17, and yet more preferably, Rb/h=11 to 15.

In order to producing the power transmission chain (1) of the third and fourth embodiments, the contact surface (14a) of the pin (14A) is formed to be in an involute shape having a basic circle of the radius R1, and the contact surface (14a) of the pin (14B) is formed to be in an involute shape having a basic circle with the radius R2, and two kinds of links (11A) (11B) in which distances between the front and back insertion parts (12) (13) are different are produced while the shapes of insertion parts (12) (13) are same, and the two kinds of links (11A) (11B) and two kinds of pins (14A) (14B) may be combined appropriately so as to make them continued.

According to the power transmission chain (1) of each embodiment described above, the locus of a contact position is set to an involute curve, whereby as shown in Fig. 13, although the pins (14) (15) are bitten by the pulley (2), the chain (1) is drawn continuously in a direction of the line L shown by an alternate long and short dash line in the Figure, whereby polygonal vibration of the chain (1) due to biting position and movement after biting can be suppressed to the minimum. In the power transmission chain

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(1) of the first and second embodiments, the locus of the
contact position of the first pins (14A) (14B) and the
second pins (15A) (15B) is an involute of a circle, and two
kinds of sets of first pins (14A) (14B) and second pins
(15A) (15B) in which the basic circle radii of involutes
are different are provided, and sets of the pins (14A)
(14B) (15A) (15B) are aligned randomly. Thereby, hammering
generation cycles are shifted and the sound energy is
dispersed to different frequencies, so it is possible to
reduce the peak of sound pressure level. In the power
transmission chain (1) of the third and fourth embodiments,
the locus of a contact position of the first pins (14A)
(14B) and the second pins (15A) (15B) is an involute of a
circle, and two kinds of sets of the first pins (14A) (14B)
and the second pins (15A) (15B) having different basic
circle radii of involutes are provided, and two kinds of
links (11A) (11B) of different pitches are aligned randomly,
whereby the peak of sound level can be further reduced. In
this way, for acute peaks in Fig. 6, energy of the sound is
distributed to different frequency bands so as to be
largely reduced, whereby noises felt by human are reduced.

In Fig. 13, it is assumed that the center of a curve
part of the chain is the origin, a direction of the linear
part of the chain is an X axis, a direction orthogonal
thereto is a Y axis, and an angle defined by a line linking

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the origin and the center of pin rolling of the chain curve

part with respect to the y axis is θ. Further, assuming

that the contact part of the pins (14A) (14B) and the

interpieces (15) when the chain is in a linear state is the

origin, a chain linear direction is an x axis, a direction

orthogonal thereto is a y axis, and an angle defined by a

pin connecting direction at the contact position of the

pins (14A) (14B) and the interpiece (15) in the chain curve

part with respect to the y axis is γ, an involute curve of

a circle is given by the following equations, where the

basic circle radius is Rb:

$x = Rb \cdot (\sin\gamma - \gamma \cdot \cos\gamma)$

$y = Rb \cdot (\cos\gamma + \gamma \cdot \sin\gamma) - Rb$

The basic circle radius Rb is the smallest radius

when used as a chain for a CVT, for example.

There are an infinite number of involute curves

corresponding to basic circle radii, and since the same

effect is maintained although the basic circle radius

varies, an allowable range of an involute curve is shown by

the following equations where R is the smallest radius of a

chain for a CVT:

$x = k \cdot R \cdot (\sin\gamma - \gamma \cdot \cos\gamma)$

$y = k \cdot R \cdot (\cos\gamma + \gamma \cdot \sin\gamma) - k \cdot R$

Here, it is preferable that k be set in the following

range, where the smallest radius of the chain curve part

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when used as a chain for a CVT is R, and transmission ratio
of CVT is r.

0.25<k<2r

That is, as shown in Fig. 14, it is possible to
reduce noises by selecting two kinds (three kinds or more
if required) of involute curves among arbitrary involute
curves between an involute curve where k=0.25 (allowable
lower limit curve) and an involute curve where k=2r
(allowable upper limit curve).

For the locus of rolling contact movement, the locus
of a contact position of the first pin and the second pin
is not limited to an involute of a circle, and it may be a
non-involute curve (involute similar curve) between an
involute curve where k=0.25 (allowable lower limit curve)
and an involute curve where k=2r (allowable upper limit
curve).

The power transmission chain described above is used
in the CVT shown in Fig. 18, and in such a case, the
interpiece (15) is set to be shorter than the pin (14), and
end faces of the pin (14) contact the conical sheave faces
(2c) (2d) of the pulley (2) in a state where end faces of
the interpiece (15) do not contact respective conical
sheave faces (2c) (2d) of the fixed sheave (2a) and the
movable sheave (2b) of the pulley (2), and power is
transmitted by a frictional force caused by this contact,

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as shown in Fig. 17. Since the pin (14) and the interpiece (15) move in a rolling and contacting manner as described above, the pin (14) will seldom rotate with respect to the sheave faces (2c) (2d) of the pulley (2), whereby frictional loss is reduced and high power transmission rate is secured.

Although the respective embodiments of the power transmission chain (1) has been explained on the premise of using the links (11), the front and back insertion parts (12) (13), the pins (14) and the interpieces (15) shown in Fig.3, shapes of the links (11), the front and back insertion parts (12) (13), the pins (14) and the interpieces (15) are not limited to those shown in Fig. 3, and are capable of being modified variously within a range where the both are capable of moving in a rolling and contacting manner relatively. Embodiments thereof will be shown in Figs. 15 and 16.

In the embodiment shown in Fig. 15, the power transmission chain (1) includes: a plurality of links (21) having front and back insertion parts (22) (23) provided at predetermined intervals in the longitudinal direction; a plurality of pins (first pins) (24) and interpieces (second pins) (25) for connecting the links (21) aligned in the chain width direction so as to be bendable in the longitudinal direction, and the links (21), the pins (24)

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and the interpieces (25) are assembled as shown in Figs. 1
and 2. The front and back insertion parts (22) (23) are
provided symmetrically, and the pin (24) and the interpiece
(25) have the same sectional shape and are drawing-
processed by using the same die.

The front insertion part (22) consists of a pin
fixing part (22a) to which the pin (24) (shown by a
continuous line) is fixed and an interpiece movable part
(22b) in which the interpiece (25) (shown by an alternate
long and two short dashes line) is movably fitted. The
back insertion part (23) consists of a pin movable part
(23a) in which the pin (24) (shown by an alternate long and
two short dashes line) is movably fitted and the interpiece
fixing part (23b) to which the interpiece (25) (shown by a
continuous line) is fixed. Since the pin (24) and the
interpiece (25) have the same sectional shape, the pin
fixing part (22a) of the front insertion part (22) and the
interpiece fixing part (23b) of the back insertion part
(23) are in the same shape (symmetrical shape), and the pin
movable part (22a) of the front insertion part (22) and the
interpiece fixing part (23b) of the back insertion part
(23) are in the same shape (symmetrical shape). In
connecting the links (21) aligned in the chain width
direction, the links (21) are overlapped such that the
front insertion part (22) of one link (21) and the back

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insertion part (23) of another link (21) correspond to each
other, and the pin (24) is fixed to the front insertion
part (22) of the one link (21) and is also movably fitted
in the back insertion part (23) of the other link (21), and
the interpiece (25) is movably fitted in the front
insertion part (22) of the one link (21) and is fixed to
the back insertion part (23) of the other link (21). Then,
the pin (24) and the interpiece (25) move in a rolling and
contacting manner relatively, which enables bending in the
longitudinal direction (front and back direction) of the
links (21).

The surface (24a) facing the interpiece (25) of the
pin (24) and the surface (25a) facing the pin (24) of the
interpiece (25) are curved surfaces, and have the same
sectional shape in which the locus of a contact position of
the pin (24) and the interpiece (25) based on the pin (24)
becomes an involute curve of a circle. That is, assuming
that the sectional curve of the contact surface (24a) of
the pin (24) is g1(y) and the sectional curve of the
contact surface (25a) of the interpiece (25) is g2(y), g1=-
g2, and if an x directional relative distance between the
sectional curve of the contact surface (24a) of the pin
(24) and the sectional curve of the contact surface (25a)
of the interpiece (25) is Lx=f(y), Lx is an involute curve.
As a result, the pin (24) and the interpiece (25) can move

relatively while rolling and contacting, and polygonal

vibration can be reduced significantly compared with a

typical silent chain.

Further, in each of the embodiments described above,

the front insertion parts (12) (22) and the back insertion

parts (13) (23) are independent through holes respectively,

but through holes for obtaining the insertion parts (12)

(22) (13) (23) may have shapes shown in Figs. 16(a) and

16(b) in order to ease stress concentration on the hole

edges. In Fig. 16(a), a link (31) has a through hole (31a)

elongated in front and back, and the front part of the

through hole (31a) is the front insertion part (32) and the

back part of the through hole (31a) is the back insertion

part (33). The through hole (31a) is in a shape in which

the front and back insertion parts (12) (13) as shown in

Fig.3 are communicated via a communication part (34), and

the shapes of the front and back insertion parts (32) (33)

shown in Fig. 16(a) are same as those of the front and back

insertion parts (12) (13) shown in Fig. 3. Therefore, by

combining them with the pins (14) and the interpieces (15)

shown in Fig. 3, there is obtained a power transmission

chain same as each embodiment of the power transmission

chain (1) mentioned above. The height of the communication

part (34) may be the height of about a several fraction of

the height of the insertion parts (32) (33) for example,

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and as shown in Fig. 16(b), a height may be close to the height of the insertion parts (32) (33) within a range not adversely affecting the movement of the pin. In Fig. 16(b), the link (31) has a through hole (31b) elongated in front and back, and the front part of the through hole (31b) is the front insertion hole (32), and the back part of the through hole (31b) is the back insertion part (33). The through hole (31b) is in a shape in which the front and back insertion parts (12) (13) shown in Fig.3 are communicated via a communication part (35), and the shapes of the front and back insertion parts (32) (33) shown in Fig. 16(b) are same as the shape of the front and back insertion parts (12) (13) shown in Fig. 3. Therefore, by combining the pin (14) and the interpiece (15) shown in Fig. 3, a power transmission chain same as the power transmission chain (1) of each embodiment is obtained.

INDUSTRIAL APPLICABILITY

The power transmission chain according to the present invention is capable of further suppressing polygonal vibration, thereby removing causes of noises. Thus, by applying this to a power transmission device of an automobile, for example, it is possible to enhance quietness of the automobile and to improve comfort.

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